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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in Anti-Icing Means for the Compressor of a Gas Turbine Engine

We, GENERAL ELECTRIC COMPANY, a Corporation organised and existing under the laws of the State of New York, United States of America, of 1, River Road, Schenectady 5, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to systems for preventing ice accumulation in the inlet passages of gas turbine engines and, more particularly, to improved valve means for controlling the flow of high temperature fluid through such anti-icing systems.

When a gas turbine engine is used to propel an aircraft, adverse atmospheric conditions encountered during flight may cause ice to form and accumulate in the inlet passage and on the inlet guide vanes. If any appreciable quantity of ice is allowed to accumulate, the compressor inlet cross-sectional area is reduced and, consequently, the amount of air flow through the engine is reduced below that called for by the angular setting of the guide vanes. The reduced air flow results in decreased thrust or power output of the engine.

Ice formation and accumulation may be prevented by extracting high temperature compressed air from the compressor discharge section or from one of the intermediate compressor stages and directing the extracted air through the variable angle inlet guide vanes. After it is passed through the interiors of the guide vanes, the air which is still at a relatively high temperature is conventionally disposed of in one of two ways, the first of these being to direct the hot air to the outside of the engine nacelle, or the fuselage in the case of a fuselage mounted engine, where it is

discharged into the atmosphere. Discharging overboard has one advantage over the second way which comprises discharging into the compressor air stream, however, in that the power loss accompanying a given percentage of extraction is much greater when discharging into the compressor air stream. For example, extraction of one percent of the air-flow as discussed with respect to dumping overboard may result in as much as a four or five percent loss in engine power when the high temperature air is returned to the air stream. This excessive power loss is undesirable and often prohibitive at the maximum power setting of the engine where the lost power cannot be recovered by going to still higher power settings.

It has been found, however, that the amount of anti-icing air required, as a percentage of the total compressor air flow, at high engine speeds is much less than that required at low speeds. It is therefore possible to dump the high temperature air back into the compressor air stream and still have an acceptably low power loss at the high power settings by reducing the percentage of air extracted at high engine speeds. Attempts have been made in the past to control the percentage of extraction by means of elaborate valve arrangements which sense the engine operating conditions and schedule the air flow accordingly. These complex valve arrangements have proved to be expensive and, because of their complexity, often unreliable.

The object of this invention to provide an improved system for preventing ice accumulation in the inlet passage of a gas turbine engine, which does not cause an excessive loss of engine power at maximum engine speed.

In accordance with the invention, an anti-

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icing means is provided for the compressor of a gas turbine engine having rotatably mounted inlet guide vanes and possibly stator vanes each formed with a cavity divided into two interconnected compartments at the leading and trailing edges thereof, and wherein a valve arrangement is provided in the rotatable supports for each vane to control the flow of a high temperature fluid into the vane compartments at the leading edges in accordance with the angular positions of the vanes. The walls of the compartments in the trailing edges of the vanes are provided with openings for the discharge of the high temperature fluid into the compressor air stream, the high temperature fluid being taken from one of the downstream stages of the compressor.

In the accompanying drawings,

Fig. 1 is a view partly in cross-section of a compressor including an inlet guide vane anti-icing system which utilizes this invention;

Fig. 2 is a detail view of a portion of the inlet guide vane structure shown in Fig. 1;

Fig. 3 is a view taken along line 3—3 of Fig. 2;

Fig. 4 is a view similar to Fig. 3 showing the spindle of the inlet guide vane in a moved position;

Fig. 5 is a view similar to Fig. 1 illustrating the utilization of the invention on an anti-icing system for both variable inlet guide vanes and variable stator vanes; and

Fig. 6 is a view similar to Fig. 1 showing a modification of the invention.

Referring first to Fig. 1, a conventional type of axial flow compressor indicated generally by the numeral 10 is illustrated. The compressor 10 includes a cylindrical front frame 11 having several support struts 12 extending radially inward from the frame 11 to support a forward fairing 13, an inner cylindrical wall 14, and a bearing 15. The front frame 11 also includes a rearwardly extending cylindrical casing 16 which forms with the inner cylindrical wall 14 an annular compressor inlet passage 17. A plurality of angularly adjustable inlet guide vanes 18 are mounted between the casing 16 and the wall 14, each guide vane 18 having a radial spindle 19 at its outer end rotatably received in a radial bore 20 extending through a boss 21 in the casing 16 as shown in Fig. 2. Each guide vane 18 also has a radial spindle 22 rotatably received in the inner cylindrical wall 14.

A cylindrical casing 25 surrounding the remainder of the compressor 10 is secured to the front frame casing 16 at the circumferential flanges 26 carried by the casings by means of bolts 27. The casing 25 supports a plurality of rows of stationary stator vanes 28. A plurality of rows of rotor blades 29 alternate with the rows of stator vanes 28. The rotor blades 29 are secured to a drum 30 which terminates in a shaft 31 at its forward end, the shaft being rotatably mounted in the

bearing 15. The clearance between the tips of the rotor blades 29 and the casing 25 is held as small as practicable in order to prevent undesirable leakage around the tips of the blades. Shroud rings 32 are supported from the inner tips of each row of stator vanes 28 to prevent undesired leakage around the inner tips of the stator vanes 28.

An annular manifold 35 is formed about the periphery of the casing 25 at one of the intermediate compressor stages, the manifold 35 being shown in Fig. 1 located just forward of the seventh row of rotor blades 29. As this description proceeds, it will become obvious to those skilled in the art that the manifold 35 can alternatively be located about other stages or about the compressor discharge section. A plurality of openings 36 are provided in the casing 25 through which high temperature compressed air is bled into the manifold 35. A pipe 37 connects the annular manifold 35 to an annular manifold 38 formed integrally with the front frame 11. An On-Off valve 39 is located in the pipe 37 to selectively permit full flow or prevent air flow through the pipe 37, the valve 39 conventionally being operated by a solenoid (not shown) controlled manually by the pilot of the aircraft.

A plurality of tubes 40 connect the annular manifold 38 to the bosses 21 in the front frame casing 16, therebeing one tube 40 leading to each boss 21 as shown in Figs. 2—4. A passage 41 aligned with the interior passage of the tube 40 is located in the boss 21 and terminates in a port in the wall of the bore 20. A similar passage or port 42 is located in the wall of the guide vane spindle 19. The ports in the bore 20 and the spindle 19 are aligned to form a maximum area opening when the spindle 19 is in one angular position as shown in Fig. 3 and misaligned to form a minimum area opening when the spindle 19 is in a second angular position as shown in Fig. 4.

Referring to Figs. 1 and 2, the radially extending spindle 19 at the outer end of each of the guide vanes 18 extends outwardly beyond the boss 21 and terminates in a reduced diameter threaded portion 45. An actuating arm 46 is connected to the spindle 19 and held in place by a nut 47 screwed onto the threaded portion 45 of the spindle 19. The angular position of the spindle 19 and its associated guide vane 18 can be varied by moving the actuating arm 46. As shown in Fig. 1, the end of the actuating arm 46 is pivotally attached to a circumferentially extending actuating ring 48 so that the guide vane 18 and the spindle 19 are rotated as the actuating ring 48 is moved circumferentially around the casing 16 by actuating means (not shown). In practice, the actuating ring 48 may be moved between two extreme positions, the first extreme position resulting in a wide

open inlet guide vane setting for maximum engine power where the maximum amount of air is allowed to flow through the compressor. At the other extreme actuating ring setting, the low power setting, the inlet guide vanes 18 are closed to permit minimum flow of air through the compressor 10.

It will be remembered at this point that a lower amount of anti-icing air is required, as a percentage of total air flow, at high power settings than at low power settings. Therefore, in accordance with this invention, the passages 42 are located on the spindle 19 so that they are aligned with the ports in the bosses 21, or the passages 41, for maximum anti-icing flow when the inlet guide vanes 18 are in their closed low power position. It will thus be obvious that Fig. 3 illustrates the alignment of the passages 41 and 42 at the low power engine setting. At higher power settings, a lower amount of anti-icing air, as a percentage of total air flow, is required. In accordance with the invention, the passages 41 and 42 are misaligned to the maximum extent when the guide vanes 18 are wide open for maximum engine power. Fig. 4 illustrates the alignment of the passages 41 and 42 at the maximum power setting. It will be noted at this point that passages 41 and 42 are illustrated as having the same area and configuration. With both passages having the same area and configuration, the change in flow area defined by passages 41 and 42 is gradual and uniform as the guide vanes 18 are moved between their extreme positions. Consequently, the percentage of anti-icing air flow is also uniformly changed. In practice, however, it may be desirable to maintain a constant flow of anti-icing air, as a percentage of total air-flow, over a broad range of engine power settings, the percentage of anti-icing air flow being reduced substantially at higher power settings. One way to accomplish this (not shown) is to make the passage 42 oversize so that the flow area begins to change only after the spindle 19 is moved a substantial amount from the low power position illustrated by Fig. 3.

As shown in Figs. 1 and 2, a radially extending partition 50 is located in the hollow interior of the guide vane 18. The air entering the interior of the guide vane 18 from the hollow spindle 19 is first directed inwardly along the leading edge of the guide vane 18 until it reaches the inner end of the radial partition 50. After reaching the inner end of the partition 50, the air can turn and flow outwardly along the trailing edge of the inlet guide vane from which it escapes into the compressor air stream through a plurality of discharge passages 51 in the wall of the guide

vane 18, or, a single discharge passage may be used if desired instead of the plurality of discharge passages 51.

Referring now to Fig. 5, the invention is shown applied to a row of inlet guide vanes 18 and, in addition, to a row of adjustable stator vanes 52. The row of adjustable stator vanes 52 are provided with radially extending spindles 53 rotatably mounted in the casing 25. An actuating arm 54 is secured to each spindle 53 in the previously described manner, and the actuating arm 54 is pivotally attached to an actuating ring 55 adapted for circumferential movement around the casing 25 by an actuating means (not shown). If desired, the actuating rings 48 and 55 may be connected for movement in unison. The adjustable stator vanes 52 are supplied with hot compressed air through tubes 56 connected to the annular manifold 38 like tubes 40. The valving arrangement for supplying the air to the stator vanes 52 and the interior directing means are substantially identical to those described with respect to the inlet guide vane 18.

Turning now to Fig. 6, the anti-icing air may alternatively be supplied to the guide vanes 18 through spindles 60 at the radially inner tips of the vanes 18. As shown by Fig. 6, the pipe 37 is directed radially inwardly through the casing 16 to an annular manifold 61 adjacent inner spindles 60. A plurality of tubes 62 connect the manifold 61 to the spindles 60, the anti-icing air thereby being supplied to the vanes 18 in a manner substantially identical to that described in detail above.

WHAT WE CLAIM IS:—

1. Anti-icing means for the compressor of a gas turbine engine having rotatably mounted inlet guide vanes and possibly stator vanes each formed with a cavity divided into two inter connected compartments at the leading and trailing edges thereof, and wherein a valve arrangement is provided in the rotatable supports for each vane to control the flow of a high temperature fluid into the vane compartments at the leading edges in accordance with the angular positions of the vanes.

2. Anti-icing means according to Claim 1, wherein the walls of the compartments in the trailing edges of the vanes are provided with openings for the discharge of the high temperature fluid into the compressor air stream.

3. Anti-icing means according to any one of the foregoing claims, wherein the high temperature fluid is taken from one of the downstream stages of the compressor.

4. Anti-icing means for the compressor of a gas turbine engine substantially as herein-

before described with reference to Figs. 1, 2,
3 and 4 or Fig. 5, or Fig. 6 of the accom-
panying drawing.

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COMPLETE SPECIFICATION

1 SHEET

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